



**University of  
Zurich**<sup>UZH</sup>

**Zurich Open Repository and  
Archive**

University of Zurich  
University Library  
Strickhofstrasse 39  
CH-8057 Zurich  
[www.zora.uzh.ch](http://www.zora.uzh.ch)

---

Year: 2014

---

## **Return to play management after concussion in football: recommendations for team physicians**

Feddermann-Demont, Nina ; Straumann, Dominik ; Dvořák, Jiří

**Abstract:** A concussion is a rare but potentially serious injury of football players. Thus, an immediate and valid diagnosis, estimate of severity and therapeutic management is required. To summarise the published information on management of concussion with respect to a safe return to play (RTP), a literature search was conducted. Current guidelines on concussion in sports and significant studies on concussion in football were analysed. After concussion, management and RTP decision should remain in the area of clinical judgement on an individualised basis according to the current international guidelines. If a concussion is suspected, the player should not be allowed to RTP the same day. The RTP programme should follow a gradual step-wise procedure. A concussed player should not RTP unless he/she is asymptomatic and the neurological and neuropsychological examinations are normal. Untimely RTP bears an increased risk of sustaining another more severe brain injury and repetitive brain injury of long-term sequelae. In football, the management of concussion should primarily follow the recommendations proposed by the Concussion in Sports Group. Information and education of players and their medical and coaching team help to protect the players' health. Future studies on concussion should include validated and detailed information on RTP protocols.

DOI: <https://doi.org/10.1080/02640414.2014.918273>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-100328>

Journal Article

Accepted Version

Originally published at:

Feddermann-Demont, Nina; Straumann, Dominik; Dvořák, Jiří (2014). Return to play management after concussion in football: recommendations for team physicians. *Journal of Sports Sciences*, 32(13):1217-1228.

DOI: <https://doi.org/10.1080/02640414.2014.918273>



**Return to play management after concussion in football:  
Recommendations for team physicians**

Journal:	<i>Journal of Sports Sciences</i>
Manuscript ID:	RJSP-2013-1128.R1
Manuscript Type:	Invited Review Article
Keywords:	sports, soccer, mild traumatic brain injury, head injury, recovery



**Return to play management after concussion in football: Recommendations for team physicians**

Nina Feddermann-Demont<sup>1, 2</sup>, Dominik Straumann<sup>1</sup>, Jiří Dvořák<sup>2, 3, 4</sup>

<sup>1</sup>Department of Neurology, University Hospital Zurich, Zurich, Switzerland

<sup>2</sup>FIFA-Medical Assessment and Research Centre, Zurich, Switzerland

<sup>3</sup>Department of Neurology, Schulthess Clinic, Zurich, Switzerland

<sup>4</sup>Fédération Internationale de Football Association (FIFA), Zurich, Switzerland

**Address correspondence and reprint requests to**

Nina Feddermann-Demont, M.D., Department of Neurology, University Hospital Zurich, Zurich, Switzerland ([Nina.Feddermann@usz.ch](mailto:Nina.Feddermann@usz.ch)); FIFA Medical Assessment and Research Centre (F-MARC), Zurich, Switzerland ([Nina.Feddermann@f-marc.com](mailto:Nina.Feddermann@f-marc.com))

**Number of words (excluding abstract, reference list, figure and tables):** 3993

**Competing interests:** None declared

**Funding:** No

**Scientific contributions of each author:**

**Nina Feddermann-Demont, MD:** First author, substantial contributions to conception and design of the manuscript; analysis of literature; drafting, writing and revision of the manuscript; final approval of the version to be published.

**Dominik Straumann, MD, Professor:** Second author, contributions to conception and design of the manuscript, writing and revision of the manuscript, final approval of the version to be published.

**Jiří Dvořák, MD, Professor:** Last author, Co-author of the Consensus Statements on Concussion in Sport, revision of the manuscript, final approval of the version to be published.

**Abstract**

**Background:** A concussion is a rare but potentially serious injury of football players. Thus, an immediate and valid diagnosis, estimate of severity and therapeutic management is required.

**Aims and methods:** To summarize the published information on management of concussion with respect to a safe return to play (RTP) a literature search was conducted. Current guidelines and significant studies on concussion in sports respectively in football were analysed.

**Results:** After concussion, management and RTP decision should remain in the area of clinical judgement on an individualised basis according to the current international guidelines. If a concussion is suspected, the player should not be allowed to RTP the same day. The RTP programme should follow a gradual step-wise procedure. A concussed player should not RTP unless he/she is asymptomatic and the neurological and neuropsychological examinations are normal. Untimely RTP bears an increased risk of sustaining another more severe brain injury and repetitive brain injury of long-term sequelae.

**Conclusion:** In football the management of concussion should primary follow the recommendations proposed by the Concussion in Sports Group. Information and education of players and their medical and coaching team help to protect the players' health. Future studies on concussion should include validated and detailed information on RTP protocols.

**Key words:** sports, soccer, mild traumatic brain injury, head injury, recovery

## INTRODUCTION

A concussion is a rare but potentially serious injury of football (soccer) players. However, frequencies are difficult to assess due to differences in definition and grading (Straume-Naesheim, Andersen, Dvorak, & Bahr, 2005): In amateur football Barnes et al. (1998) reported concussions to account for 2% to 3% of all injuries, while in professional football Nilsson et al. (Nilsson, Hagglund, Ekstrand, & Walden, 2013) (table 1) documented 0.8% of all time-loss injuries as concussions and an incidence of 0.06 per 1000 player hours. In international championships (1998 to 2012) on average 1% to 5% of all injuries were reported to be concussions (Junge & Dvorak, 2013). According to McIntosh & McCrory (2005) in youth football the incidence varies between 0.6 to 29 concussions per 1000 player hours. The incidence appears to be 2 times higher in female than in male players (Junge & Dvorak, 2013; Lincoln et al., 2011). Whether this is a true difference (e.g. because of distinct physiological constitutions or hormonal factors of female players) or due to reporting bias (with women more likely to report an injury) has not been clarified yet (Dick, 2009; Lincoln et al., 2011; Makdissi et al., 2013). Football players are much more likely to suffer a concussion during the game than during practice (Nilsson et al., 2013), according to Levy et al. (2012) up to 13 times. Contrary to American football, rugby or boxing, football is not traditionally considered to be a high risk sport for concussion (Levy et al., 2012). As in other sports, however, the total number of concussions seems to be underestimated in football (Broglia et al., 2010; Delaney, Lacroix, Leclerc, & Johnston, 2002; Khurana & Kaye, 2012; Mansell et al., 2010). In their study Broglia et al. (2010) concluded, that as many as 62% of concussions were not reported and that the majority of coaches were unable to accurately identify concussion related symptoms (table 1).

The potential short- and long-term adverse consequences of concussion require accurate diagnostic and therapeutic management strategies for gender, all ages, levels of competition

and countries. Such adverse effects include a 3 to 6 times increased risk of a subsequent more severe head (brain) injury (Colvin et al., 2009; Pellman, Viano, Casson, Arfken, & Feuer, 2005) or another injury in case of untimely return to training or play (Schneider et al., 2013). Moreover neurocognitive impairment as for instance memory, cognitive processing speed, reaction time (Colvin et al., 2009; Harmon et al., 2013) or attention (Stephens, Rutherford, Potter, & Fernie, 2010) and affective symptoms such as depression and anxiety were reported (McCrory, Meeuwisse, Aubry et al., 2013). Neurodegenerative diseases like mild cognitive impairment, Alzheimer disease (McCrory, Meeuwisse, Kutcher, Jordan, & Gardner, 2013, Godbolt et al., 2014) or chronic traumatic encephalopathy (Gavett, Stern, & McKee, 2011; McKee et al., 2009) have become object of discussion of long-term sequelae in recent years.

Currently neither an objective diagnostic clinical test nor a single marker for an immediate diagnosis of concussion at the sideline nor an approach to the clinical diagnosis of long-term effects exist (McCrory, Meeuwisse, Aubry et al., 2013). The inability to estimate injury severity at the time of injury occurrence has been observed as one of the most critical features (McCrory, Meeuwisse, Aubry et al., 2013) and underscores the need for standardized practical diagnostic tools to help team physicians and other health care providers in dealing with this potentially serious injury.

Apart from difficulties in recognizing a concussion and initiating appropriate treatment, the most important and difficult aspect of management for the team physician is the timing of return to training and play (Dvorak, McCrory, & Kirkendall, 2007; Putukian, Aubry, & McCrory, 2009; McCrory, Meeuwisse, Aubry et al., 2013). During the past 20 years different organizations and research groups have developed guidelines and positional statements for the management of concussion in football and other sports (Aubry et al., 2002; Cantu et al., 2006; Casson, Pellman, & Viano, 2009a; Doolan, Day, Maerlender, Goforth, & Gunnar Brolinson,

2012; Field, Collins, Lovell, & Maroon, 2003; Giza et al., 2013; Guskiewicz et al., 2004; Harmon et al., 2013; Kirkwood, Yeates, & Wilson, 2006; Lovell & Fazio, 2008; McCrory et al., 2005; McCrory et al., 2009; McCrory, Meeuwisse, Aubry et al., 2013). West & Marion (2014) have recently compared the current guidelines from the American Medical Society for Sports Medicine (Harmon et al., 2013), the American Academy of Neurology (Giza et al., 2013) and the expert panel of the 4th International Consensus Statement on concussion in Sport (Concussion in Sports Group) (McCrory, Meeuwisse, Aubry et al., 2013) in detail. The latter consists of 32 international experts experienced in concussion management in different sports organizations (Fédération Internationale de Football Association (FIFA), International Ice Hockey Federation (IIHF), International Olympic Committee (IOC), International Rugby Board (IRB) and Federation Equestre Internationale (FEI) (Aubry et al, 2013).

Evidence exists, however, that coaches and team physicians, who have to take the responsibility of the return to play (RTP) decision (Aubry et al., 2013), do not use these guidelines on a regular basis (Lebrun et al., 2013; Price, Malliaras, & Hudson, 2012 (table1); Yard & Comstock, 2009).

The present review summarizes the published current guidelines and analyses the scientific information on concussion in football players to arrive at sound conclusions and valid considerations that may aid team physicians in the diagnostic/therapeutic management of concussion in football with respect to a safe RTP.

## Methods

A literature search was performed in October 2013. Searches of PubMed database were undertaken using keywords “concussion”, “mild traumatic brain injury”, “head injury”, “football” and “soccer”. These words were combined with the following key words “return to play”, “rehabilitation”, “recovery”, “guidelines” and “statement”. The search was restricted to English language. Reference lists from selected articles were searched for additional relevant



articles. Current guidelines, positional statements and reviews on concussion in sports were analysed focusing on the diagnostic and therapeutic management with regard to RTP. Moreover, articles focusing on concussion in football (soccer) were evaluated with respect to adaption of the current guidelines to football.

**Results**

**Definition and pathophysiology of concussion**

Several definitions of concussion have been published (Meehan & Bachur, 2009): the Concussion in Sports Group defined concussion as „a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces“ (McCrory, Meeuwisse, Aubry et al., 2013). Although in sports the terms concussion and mild traumatic brain injury or commotio cerebri are often used as synonyms, in sports the term concussion is preferred, since signs and symptoms are not necessarily related to an actual cerebral injury (McCrory, Meeuwisse, Echemendia et al., 2013; Khurana & Kaye, 2012) nor to the Glasgow Coma Scale (GCS), which is mainly normal (GCS=15) (Taesdale & Jennett, 1974; McCrory, Meeuwisse, Echemendia et al., 2013).

So far, the pathophysiology of concussion has not been clearly understood in detail (Makdissi, 2009; McCrory, Meeuwisse, Echemendia et al., 2013). The „neurometabolic cascade“ – hypothesis constitutes a complex sequence of ionic, metabolic and pathophysiological changes that are accompanied by microscopic axonal injury leading to a mismatch between the available energy supply and the energy demand by affected neurons (Barkhoudarian, Hovda, & Giza, 2011; Vagnozzi et al., 2007). However, according to Makdissi (2009) concussion represents a functional and spontaneously recovering injury.

Animal and human studies support the concept of „post-concussive vulnerability“ predisposing for worsening of metabolic changes within the cell after a second blow before full recovery (Harmon et al., 2013). Experimental studies have demonstrated that the concussed brain is less

responsive to regular neural activation and vulnerable to prolonged dysfunction when cognitive or physical activity occurs before full recovery (Harmon et al., 2013; Vagnozzi et al., 2007). Disagreement exists about the prevalence of the „second impact syndrome” (SIS), a form of re-injury that occurs prior to the complete resolution of a previous concussion (Kutcher et al., 2010; Makdissi et al., 2013). SIS is caused by diffuse cerebrovascular deregulation and incidental herniation with brainstem failure. In literature only 17 cases of this devastating diagnosis were reported, mainly affecting players younger than 20 years of age (Kutcher, 2010). Since cases of delayed-onset diffuse cerebral oedema following relatively minor head traumas without a previously documented injury were also described, this syndrome was renamed as “malignant” or “diffuse cerebral oedema”, (Kutcher et al., 2010; McCrory, Davis & Makdissi, 2012; Makdissi et al., 2013). An association to a mutation in the CACNA1A calcium channel subunit gene was reported (Kutcher et al., 2010; Kors et al., 2001).

Please insert table 1 here

### **Management of concussion in football**

The management of concussion in football should follow the current international guidelines (Doolan et al., 2012; Finch, McCrory, Ewing, & Sullivan, 2013; Giza et al., 2013; Harmon et al., 2013; McCrory, Meeuwisse, Aubry et al., 2013). Figure 1 summarizes the most important steps and may serve as an algorithm for (team) physicians and other experienced healthcare providers in dealing with this potentially severe injury.

Please insert figure 1 here

**1 Recognition**

The first step is recognizing that a head impact has occurred (Johnston et al., 2004; McCrory, Meeuwisse, Aubry et al., 2013). The affected player should immediately be evaluated according to the standard emergency management principles (McCrory, Meeuwisse, Aubry et al., 2013) especially when the player is unconscious or unresponsive (figure 1, 1.1-1.3) (Kutcher, Giza, & Alessi, 2010, Casson et al., 2009a, Vos et al., 2013). The main concerns include the necessity of immediate life-saving procedures (1a) or neurosurgical intervention (1c), a suspected skull fracture (1d) or cervical spine injury (1b) (Casson et al., 2009a; Kutcher et al., 2010; McCrory, Meeuwisse, Aubry et al., 2013). In the latter case, it is imperative to immobilize the cervical spine. Immediate ambulance transport to the next hospital has to be organized.

Players, who are suspected to have sustained a concussion should be safely removed from training or match until evaluated by the team physician or another certified health care professional (Kutcher et al., 2010; McCrory, Meeuwisse, Aubry et al., 2013).

**2 Diagnosis**

Signs and symptoms are multifaceted and not always specific for concussion (Khurana & Kaye, 2012). According to McCrory et al. (McCrory, Meeuwisse, Aubry et al., 2013) the key signs of a concussion are mental confusion as well as memory and balance disturbance with or without loss of consciousness (LOC). In Canadian university football players, hallmark signs were considered to be confusion, disorientation and headache (Delaney, Lacroix, Gagne, & Antoniou, 2001; Delaney et al., 2002) (table 2). Attention has to be paid to diagnostic findings, which may (apart from neurocognitive impairment) exclusive be explained by affection of the central nervous system like vertical double vision or vertical nystagmus.

According to the updated European Federation of Neuroscience (EFNS) guidelines for initial management in mild traumatic brain injury (mTBI) computerized tomography (CT) is

recommended when major (e.g. GCS<15, suspected skull fracture, vomiting or post-traumatic seizure) or minor (e.g. loss of consciousness, persistent anterograde amnesia, focal deficit) risk factors were assessed. However, the team physician has to keep in mind, that intracerebral haemorrhage or oedema can develop within hours, for instance, an extradural haematoma within 6 hours. Thus the initial CT may be false negative when performed very early (within 1 h) (Smith & Miller, 1991; Vos et al., 2012).

Please insert table 2 here

Examination at sideline and in the (team) physicians office/emergency room (stadium) primary serve the team physician to rule out a (delayed) emergency situation, evaluate with regard to a (more severe) brain injury or a concussion and finally decide, if same day RTP is justifiable or not.

#### Sideline-Evaluation

The player should be observed and monitored for deterioration and other delayed life threatening neurosurgical problems ideally by the (team) physician/physician experienced in concussion and neurological examination (Casson et al., 2009a). Whenever there is suspicion of a structural cerebral lesion (figure 1, 2b), the player should immediately be taken to the closest hospital by an ambulance for further examination and (neuro)imaging of the brain or cervical spine (Casson et al., 2009a; McCrory, Meeuwisse, Aubry et al., 2013).

After an emergency situation has been ruled out, the initial assessment of concussion (figure 1, 2.1) should be guided by a symptom checklist (e.g. headache, neck pain, dizziness, blurred vision, balance problems, confusion or drowsiness), cognitive evaluation (orientation, memory, new learning, attention and concentration) and basic neurological examination including balance tests (Harmon et al., 2013; McCrory, Meeuwisse, Aubry et al., 2013).

Standardized sideline tests are a useful framework for examination, however the sensitivity, specificity, validity and reliability of these tests among different age and cultural groups and settings have not been clarified yet (Makdissi, Cantu et al., 2013). The Sport Concussion Assessment Tool-3rd edition (SCAT3<sup>TM</sup>, <http://bjsm.bmj.com/content/47/5/259.full.pdf>) for example was developed by the Concussion in Sports Group within the scope of the 4th International Consensus Statement on Concussion in Sport Conference in November 2012 organized by FIFA, IIHF, IOC, IRB and FEI. It represents a standardized method of evaluating injured players (from 13 years and older) for concussion and should only be used by medical professionals. Apart from detection of signs and symptoms SCAT3<sup>TM</sup> is also comprised of a brief neuropsychological examination (McCrory, Meeuwisse, Aubry et al., 2013), neck examination, coordination and a balance test (Davis, Iverson, Guskiewicz, Ptito, & Johnston, 2009; McCrea et al., 2003). For the evaluation of children (aged 5 to 12) child appropriate tools like the Child-SCAT3<sup>TM</sup> (<http://bjsm.bmj.com/content/47/5/263.full.pdf>) and for non-professionals the Pocket Concussion Recognition Tool (P-RCT<sup>TM</sup>, <http://bjsm.bmj.com/content/47/5/267.full.pdf>) are recommended (McCrory, Meeuwisse, Aubry et al., 2013).

Emergency Room/Office

After the sideline assessment, the (team) physician should examine the player in further detail apart from the field in a calm surrounding (emergency room or in the physicians office). This includes documentation of the specific medical history of the player (figure 1, 2.2) (Colvin et al., 2009; Makdissi, Davis et al., 2013) and completion of the neurological examination (2.3), described in detail by Casson et al. (2009a and b).

If a concussion is suspected or the physician has any diagnostic doubts, the affected player should not be allowed to return to training or play on the day of injury (Giza et al., 2013;

Harmon et al., 2013; McCrory Meeuwisse, Aubry et al., 2013). Subsequently the (team) physician has to decide, whether the player should be sent to hospital for further diagnosis and/or monitoring for 12 to 24 hours (as recommended by the EFNS guidelines for mTBI without risk factors (Vos et al., 2012)) or, if it is justifiable, to monitor the player (at the team hotel) by the team physician or send the player home, under observation of a reliable and competent person (for the first 24 hours) (Casson et al., 2009b). In the latter case the player and his/her accompanying person have to be briefed to contact the team physician or emergency department of the closest hospital in case of worsening of or new symptoms.

Concerning the return to training and play decision, the player should be instructed to physical and cognitive rest until free of initial symptoms (figure 2, stage 1) (Doolan et al., 2012) and re-evaluated by the (team) physician (Casson et al., 2009a; McCrory, Meeuwisse, Aubry et al., 2013).

Medication (e.g. pain killers for headache or neck pain) can be taken temporary to reduce symptoms, but the player should be informed about the possibility of masking disorders and that these medications have not been shown to speed up the recovery process (Doolan et al., 2012).

Following day(s)

Before initiating the RTP programme (figure 1, 3. and figure 2, stage 2), the player should be medically re-evaluated (figure 1, 2.4) usually after 24 to 48 hours focusing on the conspicuous diagnostic findings of the day of injury (Casson et al., 2009a). Moreover, an additional detailed neuropsychological examination either computer-assisted (e.g. ImPACT (Colvin, et al., 2009, [impacttest.com](http://impacttest.com)), ANAM [vitallifesciences.com](http://vitallifesciences.com), CogState/AxonSport (Straume-Naesheim, et al., 2005, [axonsports.com](http://axonsports.com)), headminders ([headminder.com](http://headminder.com)), CNS Vital Signs ([cnsvs.com](http://cnsvs.com)) or paper-pen should be performed (figure 1, 2.5), ideally interpreted by a neuropsychologist (McCrory, Meeuwisse, Aubry et al., 2013).

(Team) physicians have to keep in mind that the current tests cannot diagnose a concussion, but provide information on physiological, cognitive, psychological and behavioural changes associated with the head injury for guidance in the diagnostic/therapeutic management (McCrea, Iverson, Echemendia, Makdissi, & Raftery, 2013). Pre-season baseline-assessments can help to detect even subtle and/or individual impairments (Kutcher et al., 2010). Straume-Naesheim et al. (2005) recorded a reduction in neuropsychological performance in football players who experienced one or more head impacts in comparison to their own baseline, but when the results were compared with the test manufacturer's normative values, no impairment was detected (table 1). Colvin et al. (2009) reported that football player with a history of at least one concussion performed significantly worse on ImPACT than those without a prior concussion, and female players worse than their male counterparts (table 1). If no baseline tests are available, it is important to compare the post-injury results to robust normative measures (Echemendia et al., 2013).

### 3 Return to Play

The RTP decision should be taken by the team physician (Casson et al., 2009a; McCrory, Meeuwisse, Aubry et al., 2013). His evaluation and final decision might be conflicting with the player's desire to play, the concealment of symptoms (Kutcher, Giza, & Alessi, 2010) and/or pressure from the coaching team or media (Doolan et al., 2012).

While previous guidelines accepted same day RTP in selected cases (Casson et al., 2009a), current guidelines agree to keep the injured player out because of the previously mentioned lacking possibility to estimate injury severity at sideline (Harmon et al., 2013; McCrory, 2013). Besides (neurocognitive) impairment might develop with delay (McCrory, Meeuwisse, Aubry et al., 2013).

The player should rest cognitively and physically until initial symptoms have resolved (figure 1, 2d; figure 2, stage 1)(Casson et al., 2009a; Doolan et al., 2012; Kutcher et al., 2010; McCrory, Meeuwisse, Aubry et al., 2013), which usually takes about 24 to 48 hours (Moser, Glatts, & Schatz, 2012).

Apart from being asymptomatic, the player should not return to exercise until the neurological and neuropsychological examinations are entirely normal (figure 1, 2.4, 2.5, 2d; figure 2, stage 2). The above mentioned comparison of baseline and post-injury results can help to detect even subtle individual impairments and therefore may aid the (team) physician in her/his decision-making process (Kutcher et al., 2010).

Please insert figure 2 here

The graduated RTP protocol (figure 2), adapted from McCrory et al. (McCrory, Meeuwisse, Aubry et al., 2013) consists of six rehabilitation stages. This programme involves a step-wise



increase in physical demands (“aerobic” to “anaerobic”, “no resistance” to “resistance”), football-specific exercises (“simple” to “complex”) and the risk of contact (“individualised” to “team training”, “non-contact” to “full contact”) and head impact (“no heading” to “heading”) (Harmon et al., 2013; McCrory et al., 2009; McCrory, Meeuwisse, Aubry et al., 2013). Each stage should ideally last at least 24 hours, so that the recovery programme would take a minimum of 6 days (McCrory et al., 2009; McCrory, Meeuwisse, Aubry et al., 2013). In case of recurrence of symptoms during or after the particular tasks of one stage, the player should rest again (minimum 24 hours) until these symptoms have resolved and then restart the programme at the previous symptom-free stage (Harmon et al., 2013; McCrory et al., 2009; McCrory, Meeuwisse, Aubry et al., 2013).

Resolution of concussion symptoms typically follows a sequential course and the majority (85%) of concussion symptoms resolve within 7 to 10 days (McCrory, Meeuwisse, Aubry et al., 2013). In a large prospective cohort study of 26 European teams of professional football players, a mean layoff of 10.5 days after a concussion was reported, but almost 30% of the players already returned after five days (Nilsson et al., 2013) (table 1). In cases of certain risk factors, such as limited medical care or expertise (figure 1, 3a), a more conservative approach is recommended (Makdissi, Davis et al., 2013; McCrory, Meeuwisse, Aubry et al., 2013).

Symptoms, however, may be prolonged in some cases. If symptom resolution falls outside this usual window, it is important to consider co-existing pathologies and search for structural abnormalities if indicated (Makdissi, Davis et al., 2013, McCrory, Meeuwisse, Aubry et al., 2013). At this stage, low-level exercise and multimodal physiotherapy may prevent secondary impairments (e.g. physical deconditioning, anxiety, stress, mild depression or irritability) particularly in children and adolescents (Schneider et al., 2013).

## Children and Adolescents

The threshold necessary to evoke an injury in children has been suggested to be lower due to the poorly developed cervical musculature, the increased head to neck ratio and the developing brain and skull (Kirkwood et al., 2006; Makdissi et al., 2013). Moreover, evidence exists, that resolution of concussion symptoms, including the recovery of cognitive deficits, takes longer in children (Purcell, 2009; Makdissi et al., 2013). Children are not “little adults” and therefore concussion management should differ and be age-adapted (Kirkwood et al., 2006). (Team) physicians have to take into consideration non-sport-specific aspects, such as return to school, which should precede RTP (Makdissi et al., 2013). This implies information and education of parents and teachers in respect to concussion characteristics and consequences (Kirkwood et al., 2006) and may require adaptations of class schedule (Makdissi et al., 2013). Although the course of concussion in children is usually benign, the previously discussed graduated RTP protocol should be more conservative and cautious (ideally last at least 2 weeks) (Kirkwood et al., 2006; Meehan & Bachur, 2009; Purcell, 2009; Makdissi et al., 2013). Physicians should keep in mind, that repeated concussions can lead to decreased neurocognitive function or increased symptoms and, as mentioned previously, in selected cases to catastrophic outcomes (Makdissi, Davis et al., 2013; Meehan & Bachur, 2009, McCrory, Davis & Makdissi, 2012). Recovery in children should therefore be monitored thoroughly by serial physical examination and standardized behavioral instrumentation (Kirkwood et al., 2006).

## Additional Examinations

Additional examinations should be performed if indicated or if symptoms are longer lasting as part of a multidisciplinary diagnostic and therapeutic approach: cranial MRI to exclude a structural brain injury (Giza et al., 2013; Harmon et al., 2013; McCrory, Meeuwisse, Aubry et al., 2013), functional vestibular (e.g. video-head impulse test) and ocular motor tests in case

of vestibular symptoms (e.g. vertigo, dizziness or blurred vision), orthopaedic examination for cervical spine dysfunction or psychological evaluation for affective disorders such as depression, irritability and anxiety (McCrory, Meeuwisse, Kutcher et al., 2013).

Apart from the above-mentioned examinations, the following tests require further research before they can be recommended on a regular base (Kutcher et al., 2013): Functional MRI may correlate with injury severity and provide additional insight in pathophysiological mechanism. Positron emission tomography (PET), diffusion tensor imaging (DTI), diffusion weighted imaging (DWI), diffusion spectrum imaging (DSI) and single- photon emission tomography (SPECT) are at their early research stages in the context of concussion (McCrory, Meeuwisse, Aubry et al., 2013). The same is true for genetic testing/marker or biomarker like Apolipoprotein E4 (APOE4), Apo E promoter gene, Tau polymerase and cytokine factors. However APOE4 has been suggested to be associated with unfavourable outcome (Khurana & Kaye, 2012). The significance of the biochemical serum and cerebral spinal fluid biomarkers S-100B, Neuron-specific enolase (NSE), Myelin basic protein (MBP), Glial fibrillary acidic protein (GFAP) and Tau has not been clarified yet, but have been proposed as means for cellular damage (McCrory, Meeuwisse, Aubry et al., 2013).

The meaning of electrophysiological recording techniques like electroencephalography (EEG) is unclear (McCrory, Meeuwisse, Aubry et al., 2013).

**Conclusion**

Due to the heterogeneity of signs and symptoms, the management of concussion requires a multifaceted approach. In football physicians and other healthcare providers should primary follow the recommendations proposed by the Concussion in Sports Group (McCrory, Meeuwisse, Aubry et al., 2013). The decision on a safe RTP is in the responsibility of the team physician and should follow an individualized and gradual step-wise rehabilitation programme. Distribution of information and education on characteristics of concussion of

1  
2  
3 football players and their medical and coaching team should help to protect their health and to  
4  
5 identify players at an increased risk for short and long term sequelae. Apart from further  
6  
7 research on pathophysiology, diagnosis and classification of concussion, future studies should  
8  
9 include validated and detailed information on RTP protocols  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For Peer Review Only

References

Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J., ... Schamasch P. (2002). Summary and agreement statement of the First International Conference on Concussion in Sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med*, 36(1), 6-10.

Aubry, M., Dvorak, J., McCrory, P., Meeuwisse, W., Raftery, M., Sills, A., Engebretsen L. (2013). Zero tolerance: the future of head injury in sports. *Br J Sports Med*, 47(5), 249.

Barkhoudarian, G., Hovda, D. A., & Giza, C. C. (2011). The molecular pathophysiology of concussive brain injury. *Clin Sports Med*, 30(1), 33-48, vii-iii.

Barnes, B. C., Cooper, L., Kirkendall, D. T., McDermott, T. P., Jordan, B. D., & Garrett, W. E., Jr. (1998). Concussion history in elite male and female soccer players. *Am J Sports Med*, 26(3), 433-438.

Broglio, S. P., Vagnozzi, R., Sabin, M., Signoretti, S., Tavazzi, B., & Lazzarino, G. (2010). Concussion occurrence and knowledge in italian football (soccer). *J Sports Sci Med*, 9(3), 418-430.

Cantu, R. C., Aubry, M., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J., ... McLeod T. C. (2006). Overview of concussion consensus statements since 2000. *Neurosurg Focus*, 21(4), E3.

Casson, I. R., Pellman, E. J., & Viano, D. C. (2009a). Concussion in the National Football League: an overview for neurologists. *Phys Med Rehabil Clin N Am*, 20(1), 195-214, x.

Casson, I. R., Pellman, E. J., & Viano, D. C. (2009b). National football league experiences with return to play after concussion. *Arch Neurol*, 66(3), 419-420.

Cernich, A., Reeves, D., Sun, W., & Bleiberg, J. (2007). Automated Neuropsychological Assessment Metrics sports medicine battery. *Arch Clin Neuropsychol*, 22 Suppl 1, S101-114.

Colvin, A. C., Mullen, J., Lovell, M. R., West, R. V., Collins, M. W., & Groh, M. (2009). The role of concussion history and gender in recovery from soccer-related concussion. *Am J Sports Med*, 37(9), 1699-1704.

Davis, G. A., Iverson, G. L., Guskiewicz, K. M., Ptito, A., & Johnston, K. M. (2009). Contributions of neuroimaging, balance testing, electrophysiology and blood markers to the assessment of sport-related concussion. *Br J Sports Med*, 43 Suppl 1, i36-45.

Delaney, J. S., Lacroix, V. J., Gagne, C., & Antoniou, J. (2001). Concussions among university football and soccer players: a pilot study. *Clin J Sport Med*, 11(4), 234-240.

Delaney, J. S., Lacroix, V. J., Leclerc, S., & Johnston, K. M. (2002). Concussions among university football and soccer players. *Clin J Sport Med*, 12(6), 331-338.

Dick, R. W. (2009). Is there a gender difference in concussion incidence and outcomes? *Br J Sports Med*, 43 Suppl 1, i46-50.

Doolan, A. W., Day, D. D., Maerlender, A. C., Goforth, M., & Gunnar Brolinson, P. (2012). A review of return to play issues and sports-related concussion. *Ann Biomed Eng*, 40(1), 106-113.

Dvorak, J., McCrory, P., & Kirkendall, D. T. (2007). Head injuries in the female football player: incidence, mechanisms, risk factors and management. *Br J Sports Med*, 41 Suppl 1, i44-46.

- Echemendia, R. J., Iverson, G. L., McCrea, M., Macciocchi, S. N., Gioia, G.A., Putukian, M., Comper, P. (2013). Advances in neuropsychological assessment of sports-related concussion. *Br J Sports Med*, 47(5):294-8.
- Field, M., Collins, M. W., Lovell, M. R., & Maroon, J. (2003). Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. *J Pediatr*, 142(5), 546-553.
- Finch, C. F., McCrory, P., Ewing, M. T., & Sullivan, S. J. (2013). Concussion guidelines need to move from only expert content to also include implementation and dissemination strategies. *Br J Sports Med*, 47(1), 12-14.
- Gavett, B. E., Stern, R. A., & McKee, A. C. (2011). Chronic traumatic encephalopathy: a potential late effect of sport-related concussive and subconcussive head trauma. *Clin Sports Med*, 30(1), 179-188, xi.
- Giza, C. C., Kutcher, J. S., Ashwal, S., Barth, J., Getchius, T. S., Gioia, G. A., ... Zafonte, R. (2013). Summary of evidence-based guideline update: Evaluation and management of concussion in sports: Report of the Guideline Development Subcommittee of the American Academy of Neurology. *Neurology*, 11;80(24):2250-7.
- Godbolt, A.K., Cancelliere, C.Hincapié, C.A., Marras, C., Boyle, E., Kristman V.L., ... Cassidy, J. D. (2014). Systematic Review of the Risk of Dementia and Chronic Cognitive Impairment After Mild Traumatic Brain Injury: Results of the International Collaboration on Mild Traumatic Brain Injury Prognosis. *Arch Phys Med Rehabil*, 95(3S):S245-S256.
- Guskiewicz, K. M., Bruce, S. L., Cantu, R. C., Ferrara, M. S., Kelly, J. P., McCrea, M., ... McLeod, T. C. (2004). National Athletic Trainers' Association Position Statement: Management of Sport-Related Concussion. *J Athl Train*, 39(3), 280-297.
- Harmon, K. G., Drezner, J., Gammons, M., Guskiewicz, K., Halstead, M., Herring, S., ... Roberts, W. O. (2013). American medical society for sports medicine position statement: concussion in sport. *Clin J Sport Med*, 23(1), 1-18.
- Johnston, K. M., Bloom, G. A., Ramsay, J., Kissick, J., Montgomery, D., Foley, D., ... Ptito, A. (2004). Current concepts in concussion rehabilitation. *Curr Sports Med Rep*, 3(6), 316-323.
- Junge, A., & Dvorak, J. (2013). Injury surveillance in the World Football Tournaments 1998-2012. *Br J Sports Med*, 47(12), 782-788.
- Khurana, V. G., & Kaye, A. H. (2012). An overview of concussion in sport. *J Clin Neurosci*, 19(1), 1-11.
- Kirkwood, M. W., Yeates, K. O., & Wilson, P. E. (2006). Pediatric sport-related concussion: a review of the clinical management of an oft-neglected population. *Pediatrics*, 117(4), 1359-1371.
- Kors E. E., Terwindt G. M., Vermeulen F. L., Fitzsimons R. B., Jardine P. E., Heywood P., ... Ferrari, M.D. (2001). Delayed cerebral edema and fatal coma after minor head trauma: role of the CACNA1A calcium channel subunit gene and relationship with familial hemiplegic migraine. *Ann Neurol*, 49(6):753-760
- Kutcher, J. S. (2010). Management of the complicated sports concussion patient. *Sports Health*, 2(3), 197-202.
- Kutcher, J. S., Giza, C. C., & Alessi, A. G. (2010). Sports concussion. *Continuum (Minneapolis)*, 16(6 Traumatic Brain Injury), 41-54.
- Kutcher, J. S., McCrory, P., Davis, G., Ptito, A., Meeuwisse, W. H., & Broglio, S. P. (2013). What evidence exists for new strategies or technologies in the diagnosis of sports concussion and assessment of recovery? *Br J Sports Med*, 47(5), 299-303.
- Lebrun, C. M., Mrazik, M., Prasad, A. S., Tjarks, B. J., Dorman, J. C., Bergeron, M. F., ... Valentine, V. D. (2013). Sport concussion knowledge base, clinical practises and



needs for continuing medical education: a survey of family physicians and cross-border comparison. *Br J Sports Med*, 47(1), 54-59.

Levy, M. L., Kasasbeh, A. S., Baird, L. C., Amene, C., Skeen, J., & Marshall, L. (2012). Concussions in soccer: a current understanding. *World Neurosurg*, 78(5), 535-544.

Lincoln, A. E., Caswell, S. V., Almquist, J. L., Dunn, R. E., Norris, J. B., & Hinton, R. Y. (2011). Trends in concussion incidence in high school sports: a prospective 11-year study. *Am J Sports Med*, 39(5), 958-963.

Lovell, M. R., & Fazio, V. (2008). Concussion management in the child and adolescent athlete. *Curr Sports Med Rep*, 7(1), 12-15.

Makdissi, M. (2009). Is the simple versus complex classification of concussion a valid and useful differentiation? *Br J Sports Med*, 43 Suppl 1, i23-27.

Makdissi, M., Cantu, R. C., Johnston, K. M., McCrory, P., & Meeuwisse, W. H. (2013). The difficult concussion patient: what is the best approach to investigation and management of persistent (>10 days) postconcussive symptoms? *Br J Sports Med*, 47(5), 308-313.

Makdissi, M., Davis, G., Jordan, B., Patricios, J., Purcell, L., & Putukian, M. (2013). Revisiting the modifiers: how should the evaluation and management of acute concussions differ in specific groups? *Br J Sports Med*, 47(5), 314-320.

Mansell, J. L., Tierney, R. T., Higgins, M., McDevitt, J., Toone, N., & Glutting, J. (2010). Concussive signs and symptoms following head impacts in collegiate athletes. *Brain Inj*, 24(9), 1070-1074.

McCrea, M., Guskiewicz, K. M., Marshall, S. W., Barr, W., Randolph, C., Cantu, R. C., ... Kelly, J. P. (2003). Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA*, 290(19), 2556-2563.

McCrea, M., Iverson, G. L., Echemendia, R. J., Makdissi, M., & Raftery, M. (2013). Day of injury assessment of sport-related concussion. *Br J Sports Med*, 47(5), 272-284.

McCrory, P. (2013). Traumatic brain injury: revisiting the AAN guidelines on sport-related concussion. *Nat Rev Neurol*, 9(7), 361-362.

McCrory, P., Davis, G., Makdissi, M. (2012). Second Impact Syndrome or Cerebral Swelling after Sporting Head Injury. *Curr Sports Med Rep*. 11(1):21-3.

McCrory, P., Johnston, K., Meeuwisse, W., Aubry, M., Cantu, R., Dvorak, J., ... Schamasch, P. (2005). Summary and agreement statement of the second international conference on concussion in sport, prague 2004. *Phys Sportsmed*, 33(4), 29-44.

McCrory, P., Meeuwisse, W., Johnston, K., Dvorak, J., Aubry, M., Molloy, M., Cantu, R. (2009). Consensus statement on concussion in sport - the Third International Conference on Concussion in Sport held in Zurich, November 2008. *Phys Sportsmed*, 37(2), 141-159.

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, B., Dvorak, J., Echemendia, R. J., ... Turner, M. (2013). Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med*, 47(5), 250-258.

McCrory, P., Meeuwisse, W. H., Echemendia, R. J., Iverson, G. L., Dvorak, J., & Kutcher, J. S. (2013). What is the lowest threshold to make a diagnosis of concussion? *Br J Sports Med*, 47(5), 268-271.

McCrory, P., Meeuwisse, W. H., Kutcher, J. S., Jordan, B. D., & Gardner, A. (2013). What is the evidence for chronic concussion-related changes in retired athletes: behavioural, pathological and clinical outcomes? *Br J Sports Med*, 47(5), 327-330.

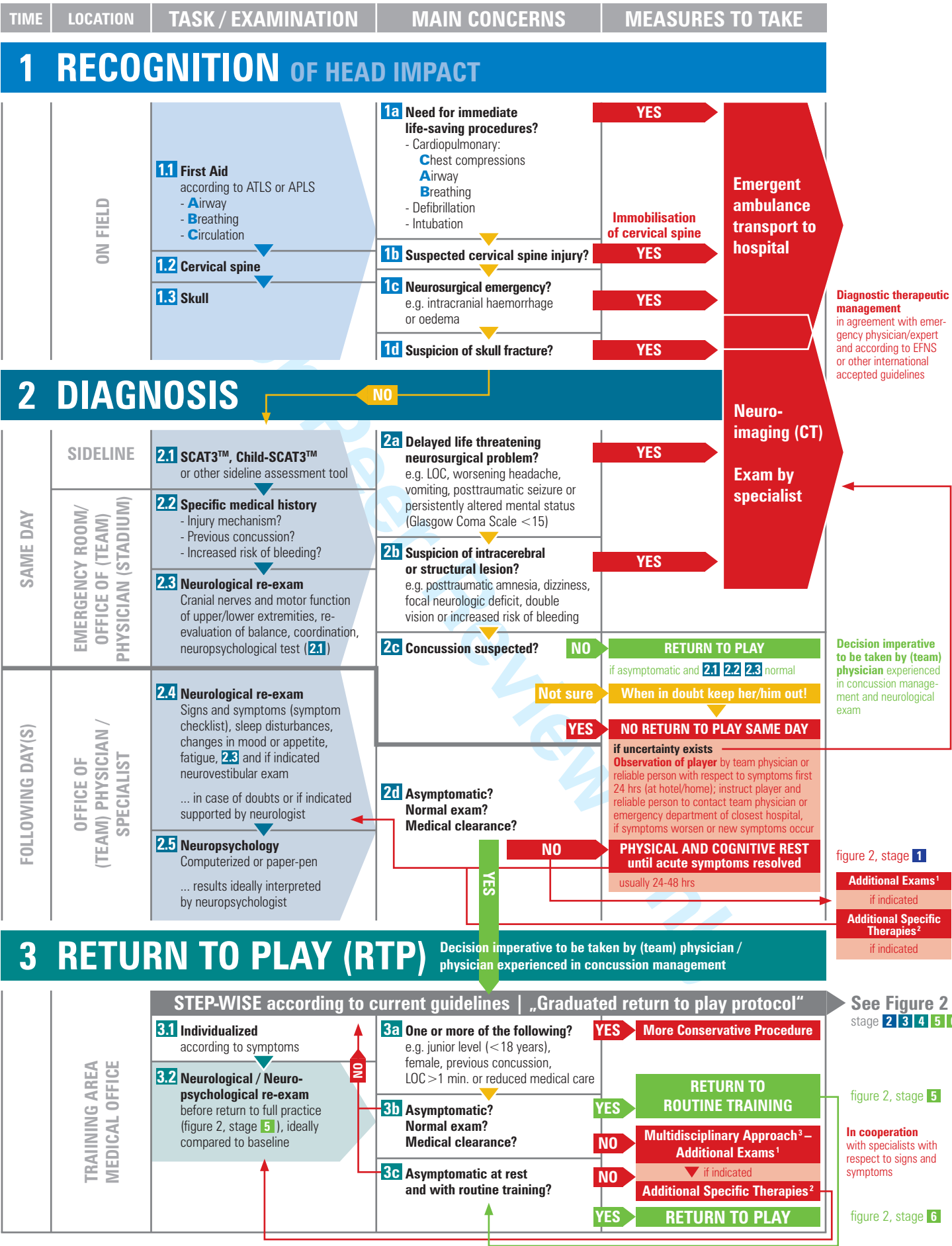
McIntosh, A. S., & McCrory, P. (2005). Preventing head and neck injury. *Br J Sports Med*, 39(6), 314-318.

- McKee, A. C., Cantu, R. C., Nowinski, C. J., Hedley-Whyte, E. T., Gavett, B. E., Budson, A. E., ... Stern, R. A. (2009). Chronic traumatic encephalopathy in athletes: progressive tauopathy after repetitive head injury. *J Neuropathol Exp Neurol*, 68(7), 709-735.
- Meehan, W. P., 3rd, & Bachur, R. G. (2009). Sport-related concussion. *Pediatrics*, 123(1), 114-123.
- Moser, R. S., Glatts, C., & Schatz, P. (2012). Efficacy of immediate and delayed cognitive and physical rest for treatment of sports-related concussion. *J Pediatr*, 161(5), 922-926.
- Nilsson, M., Hagglund, M., Ekstrand, J., & Walden, M. (2013). Head and neck injuries in professional soccer. *Clin J Sport Med*, 23(4), 255-260.
- Pellman, E. J., Viano, D. C., Casson, I. R., Arfken, C., & Feuer, H. (2005). Concussion in professional football: players returning to the same game--part 7. *Neurosurgery*, 56(1), 79-90; discussion 90-72.
- Price, J., Malliaras, P., & Hudson, Z. (2012). Current practices in determining return to play following head injury in professional football in the UK. *Br J Sports Med*, 46(14), 1000-1003.
- Purcell, L. (2009). What are the most appropriate return-to-play guidelines for concussed child athletes? *Br J Sports Med*, 43 Suppl 1, i51-55.
- Putukian, M., Aubry, M., & McCrory, P. (2009). Return to play after sports concussion in elite and non-elite athletes? *Br J Sports Med*, 43 Suppl 1, i28-31.
- Schneider K. J., Iverson G. L., Emery C. A., McCrory P., Herring S. A., Meeuwisse W. H. (2013). The effects of rest and treatment following sport-related concussion: a systematic review of the literature. *Br J Sports Med*, 47(5):304-7.
- Shenouda, C., Hendrickson, P., Davenport, K., Barber, J., & Bell, K. R. (2012). The effects of concussion legislation one year later--what have we learned: a descriptive pilot survey of youth soccer player associates. *PM R*, 4(6), 427-435.
- Smith, H.K., Miller, J.D. (1991). The danger of an ultra-early computed tomographic scan in a patient with an evolving acute epidural hematoma. *Neurosurgery*, 29: 258-260.
- Stephens, R., Rutherford, A., Potter, D., & Fernie, G. (2010). Neuropsychological consequence of soccer play in adolescent U.K. School team soccer players. *J Neuropsychiatry Clin Neurosci*, 22(3), 295-303.
- Straume-Naesheim, T. M., Andersen, T. E., Dvorak, J., & Bahr, R. (2005). Effects of heading exposure and previous concussions on neuropsychological performance among Norwegian elite footballers. *Br J Sports Med*, 39 Suppl 1, i70-77.
- Teasdale G., Jennett B. (1974). Assessment of coma and impaired consciousness. A practical scale. *Lancet*, 2(7872):81-4.
- Vagnozzi, R., Tavazzi, B., Signoretti, S., Amorini, A. M., Belli, A., Cimatti, M., ... Lazzarino, G. (2007). Temporal window of metabolic brain vulnerability to concussions: mitochondrial-related impairment--part I. *Neurosurgery*, 61(2), 379-388; discussion 388-379.
- Vos, P. E., Alekseenko, Y., Battistin, L., Ehler, E., Gerstenbrand, F., Muresanu, D. F., ... von Wild, K. (2012). Mild traumatic brain injury. *Eur J Neurol*, 19(2):191-8.
- West, T. A., & Marion, D. W. (2014). Current Recommendations for the Diagnosis and Treatment of Concussion in Sport: A Comparison of Three New Guidelines. *J Neurotrauma*, 15;31(2):159-68.
- Yard, E. E., & Comstock, R. D. (2009). Compliance with return to play guidelines following concussion in US high school athletes, 2005-2008. *Brain Inj*, 23(11), 888-898.



Figure 1: ALGORITHM OF CONCUSSION

based on Giza et al., 2013, Harmon et al., 2013, McCrory et al., 2013 and Vos et al., 2012



Remarks: <sup>1</sup> e.g. functional vestibular and ocular motor tests, orthopaedic exam, psychiatric evaluation or neuroimaging (MRI) | <sup>2</sup> e.g. repositioning manoeuvres in case of BPPV or PT in case of cervical spine impairment  
<sup>3</sup> In case of prolonged symptoms (>10days) an evaluation by a specialist or physician experienced in concussion management is recommended. Moreover, other diagnoses should be taken into consideration.

Abbreviations: ATLS: Advanced Trauma Life Support | APLS: Advanced Pediatric Life Support | BPPV: Benign paroxysmal positional vertigo | Child-SCAT3™: Child Short Concussion Assessment Tool | CT: Computerized Tomography  
EFNS: European Federation of Neurological Societies | Exam: Examination | hrs: hours | LOC: Loss of consciousness | min.: minute(s) | MRI: Magnetic Resonance Imaging | PT: Physiotherapy | SCAT3™: Sport Concussion Assessment Tool - 3rd Edition

URL: <http://mc.manuscriptcentral.com/jrsp>

## Figure 2: CONCUSSION – GRADUATED RETURN TO PLAY PROTOCOL

adapted from McCrory et al., 2013

Stage	Rehabilitation Programme	Functional Exercise	Objective
1	NO ACTIVITY	<b>Symptom limited rest</b> - Physical (no exercise) - Cognitive (no TV, PC, gaming or intensive reading)	Recovery
2	LIGHT EXERCISE	Following medical clearance (figure 1 2d) - Walking, swimming or stationary cycling - Intensity <70% maximum predicted heart rate (aerobic training) - No resistance training	Activation of cardiovascular circulation
3	FOOTBALL-SPECIFIC EXERCISE	Individualised training - Running drills (aerobic) - May start progressive anaerobic running drills - No head impact activities	Football specific movement and coordination skills
4	NON-CONTACT TRAINING DRILLS	- More complex training drills (e.g. passing) and explosive movements - Progression from aerobic to anaerobic exercises	Increase of exercise -, coordination - and cognitive load
5	RETURN TO ROUTINE TRAINING	Following medical clearance (figure 1 3b) Full contact practice (participation in normal training activities of team)	Restoration of confidence and assessment of functional skills by coaching staff
6	RETURN TO PLAY	<b>Normal match play</b>	

**Remarks:** Each stage should take at least 24 hours. In case of recurrence of symptoms, the player should rest again until these symptoms have resolved and then restart the programme at the previous asymptomatic stage.

URL: <http://mc.manuscriptcentral.com/rjss>

Table 1: Studies on management of concussion in football (soccer)

Author, year, country	Level of play	Study Design	Sample size/Number of players (N)	Age in years	Definition of Concussion	Objective	Methods	Results
Nilsson et al., 2013, 10 European countries	Professional International	Prospective cohort	N=1401	25.8		Rate and risk factors of concussion	Evaluation of men's professional football in Europe	Incidence 0.06 per 1000 player hours, 78-fold higher rate during match than training; Mean layoff 10.5 days, Return to play of 27% of concussed players within 5 days
Price et al., 2012, England	Professional	Survey	92 Clubs		"standardized definition"	Current practices of the Consensus in Sport guideline	Questionnaire	2008 Zurich Consensus Statement unknown by a quarter of teams, significantly widened gap at lower leagues
Straume-Næsheim et al., 2009, Norway	Professional	Prospective case-control	N=462	25.2		Impairment in brain function after concussion	Pre-season baseline neuropsychological testing, follow-up after head impact, Videotapes	Reduction in neuropsychological performance in players who experienced 1 or more head impacts when tested before following season; none impaired when compared with the test manufacturer's normative data
Stephens et al., 2010, United Kingdom	Amateur	Quasi-experimental cross-sectional	N=48	14.8	"head injuries without LOC"	Neuropsychological consequences of concussion	Interview, WISC-R vocabulary subtest, Childhood Depression Inventory Short Form (CDI-S), 13 neuropsychological tests	No evidence of neuropsychological decrement; poorer attention performance with increasing concussive head injury
Delaney et al., 2001, Canada	University	Retrospective survey	N=52, w=25, m=27	20.6	"LOC, confusion or disorientation, or any of the other most commonly accepted symptoms of a concussion after being hit on the head playing football"	Incidence and characteristics of concussion	Questionnaire	11 times greater chance of concussion after previous concussion; persistence of concussion symptoms in 18.1% for at least 1 day; most common symptoms: confusion/disorientation
Delaney et al., 2002, Canada	University	Retrospective survey	N=201, w=110, m=82, na=9	20.9	"LOC, confusion or disorientation, or any of the other most commonly recognized concussion symptoms after being hit in the head playing" football	Incidence and characteristics of concussion	Questionnaire	Realization of concussion symptoms by 19.8% of football players; >3 times greater risk after previous concussion, females > 2.5 times as likely as males. Symptom duration for at least 1 day in 18.8%. Most common symptoms: headache > confusion > disorientation
Colvin et al., 2009, USA	High School	Prospective cohort	N=234, w=141, m=93	16.4	"traumatically induced alteration in mental status with or without LOC"	Gender differences in recovery after concussion	Clinical interview, ImPACT	Significant worse ImPACT performance in football players if at least 1 previous concussion, and if female; more symptoms in females than in males
Broglio et al., 2010, Italy	Youth	Survey	N=727	16.8	"blow to head, that causes a variety of symptoms that may last for a short or longer period of time"	Occurrence and knowledge of concussion	Survey distribution	High number of unreported concussions and lacking knowledge about concussive injuries outside of the United States
Shenouda et al., 2012, USA	Youth	Survey	N=391			Assessment of knowledge of parents, coaches and officials regarding concussion and return to play guidelines	Survey distribution	Existence of lacking knowledge and practice regarding concussion

Abbreviations: w=women, m=men, LOC=Loss of Consciousness, ImPACT=Immediate Post-Concussion Assessment and Cognitive Testing

**Table 2: Signs and Symptoms of concussion**  
according to McCrory et al., 2013

<b>Emergency Symptoms</b>	<b>Hallmark Signs</b>
Glasgow Coma Scale < 15 Deteriorating mental status Potential spinal injury Progressive, worsening symptoms New neurologic signs	Mental confusion Memory disturbance Balance disturbance
<b>Most common Symptoms first 24 hrs</b>	<b>Common Symptoms days after injury</b>
Headache Nausea Dizziness Balance problems Blurred vision Confusion Memory loss Fatigue	Tiredness Irritability Nervousness Anxiety Sleep disturbance Sensitivity to light Sensitivity to noise